THE WHEEL-LIKE AND OTHER SPICULA OF THE CHIRODOTA OF BERMUDA.

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[SEE PLATE II.]

The fact that what little I can find written about the beautiful and curious spicula of the *Chirodota* is singularly inaccurate and misleading, induces me to select for the subject of this paper a description of these spicula, their manner of growth, and some of the more striking features of the animal itself. In none of the works on microscopy do I find a correct description of the spicula. They are simply called "wheels,"—and Carpenter adds, "These 'wheels' are objects of singular beauty and delicacy, being especially remarkable for the very minute notching which is traceable round the inner margins of the 'tires.'" This quotation from one of the most distinguished of observers shows that he had no correct idea of the "singular beauty and delicacy" of the object under consideration. Nor in any work on Zöology do I find any mention of the manner of growth of these spicula; which is so extraordinary in itself, and so widely different from the mode of growth of the spicula found in all the other members of the Holothurian family, that it seems to me it must have escaped notice entirely, or it would have received more attention. I can explain the failure of naturalists to observe and comment upon these singular features of growth, form, etc., only by supposing that they have jumped to the conclusion

that they grew like all the other spicula of the Holothurian family, or that the *Chirodota* I know is a very different creature from what has been seen by other observers. The latter supposition is not at all probable; for, although I have never seen the "wheels" from any other source, I think, from the descriptions given of them, that they are very similar to the Bermudian, the only species with which I am acquainted. While it is not at all probable there is any difference of importance in the species found in Bermuda and elsewhere, I wish it understood that my remarks apply wholly to the Bermudian species. I found them first in January, 1877, and my pleasure at the discovery may be imagined, for I was totally ignorant of their presence in those islands.

In attempting to describe the principal kind of spicula of the *Chirodota* I am at a loss for a proper object of comparison. That they should receive the name "wheels" when viewed as commonly mounted in balsam is not surprising, for then their resemblance to a wheel is most striking; but when one comes to see them opaque objects and understand what their structure really is, the comparison to a wheel seems unsatisfactory and far-fetched. The only kind of a wheel to which they can be at all properly compared, is that technically known as a "crown wheel,"—that is, a kind of wheel with a broad tire or rim, with cogs upon one side of the tire. To me it seems more like a flatted crown. In attempting to make out the structure accurately, many difficulties present themselves from the very transparent and glass-like material of which they are composed.

In order to describe a spiculum, I will begin at the "tire," or rim. This rim is broad, and slopes from the bottom to the top; that is, the top forms a circle less in diameter than the bottom. The top side of the rim is beautifully ornamented with regular tooth-like projections. The grooves between the "cogs" extend about one-half the width of the rim. This sloping of the sides of the rim accounts for a certain optical illusion, to be mentioned farther on. The spokes, which are generally six in number, spring from the bottom side of the rim, and, making a double curve, like the "line of beauty," reach the axis, or hub of the wheel, which is rounded on top, and cup-shaped beneath. The rounded top of the

hub is generally on a level with the top of the rim, sometimes a little higher. When viewed directly from the top, the "hub" seems pointed; but this is an optical effect, produced by the manner of union of the spokes on the under side. The spokes are broad and grooved, the convex surface being toward the upper surface of the spiculum; and, as they enter the hub, seem to narrow the groove, and look not unlike tenons of spokes entering a transparent hub. In the center of the cup-shaped hollow of the under side of the hub is a conical, pointed elevation, reaching nearly to the plane of the lower side of the wheel. It is this conical piece, I think, which makes the really rounded hub on the upper side look sharp-pointed.

When the wheel is mounted in balsam, its appearance is greatly changed. It looks like a flat wheel with a wide "tire," the inner edge of which appears beautifully beveled between the spokes; and the edge itself is elegantly ornamented with regular tooth-like projections, or "cogs," as they have been called. These cogs, as we have seen, are really upon the upper side of the sloping rim; which slope, bringing the top nearer to the center than the bottom, and looking down through the transparent material, makes it look like a flat tire, with the teeth or cogs on the inside. By careful focusing, the conical point under the hub may be made to appear like a sharp, bright point, apparently turned toward the observer, whereas it is turned directly from him. The spokes appear nearly flat, with rounded edges, till they near the hub, when they seem to narrow to tenons, with the hub spreading out between the spokes. The wheels vary in diameter from $\frac{1}{200}$ to $\frac{1}{300}$ of an inch.

When we come to consider the mode of growth and development of these beautiful spicula, I think we have before us one of the most curious things to be met with in the whole animal world. It is entirely unique in relation to the growth of any of the spicula of the Holothurian family. Carpenter says: "There can scarcely be a reasonable doubt that every member of this order has a calcareous skeleton, disposed in a manner conformable to the examples now cited," referring to the usual manner of these spicula being buried in the integument of these animals. Huxley says: "In other *Holothuroidea* the skeleton may attain a much greater development, and even take the form of conspicuous, over-lapping plates," and men-

tions the *Psolus* as an example. I have seen some species of this family where the spicula were so abundant as to give the integument a stiff, rough feel, and apparently needing but a little greater development to reach the solid box or "test" of the "sea-urchins."

In the *Chirodota*, instead of the wheel-like spicula being scattered through the integument, as is generally the case, they are found in little sacs, which at first glance look like hollow spheres coated with wheels,—so transparent is the material of which the center of the sphere is composed. In many cases the wheels do not cover the whole surface of the sphere, but leave a portion free. Upon closer examination it is found these apparently hollow balls of wheels are filled with a complicated structure that has furnished the material of which these wheels are made. By carefully dissolving out the calcareous matter it is found that each wheel is covered with transparent "periosteum," if you please to call it so. Whatever it may be termed, there is a membrane of extreme tenacity, of the exact form of the wheel, a sort of shadowing ghost of the former solid substance. On this ball or sphere the wheels are all arranged with the toothed or ornamented edge of the rim outward. Extending from the center of each wheel, from the cup-shaped cavity in the under, now inner, side, is a cord which connects it with the central mass of the sphere. I can compare this only to the "umbilical cord," for it is evidently the medium through which all the material for the growth of the wheel is carried, and it also serves to connect it with the general mass. The length of the cord is equal to about the diameter of the wheel. At the outer end it divides into lobe-like expansions, each lobe going to its particular spoke, the conical point in the center of the hub fitting in between the lobes. The end of the cord toward the central part of the sphere connects with fibers running over the outer surface of a sort of inner sphere of granular matter, these fibers running through it in all directions as well as over its surface, and connecting the various cords. The matter of this internal mass is hard to make out. Besides the fibres, a few cells are seen, and some granular matter. Sometimes when a ball of wheels is removed from the integument it is covered with an envelope or membrane. This is so extremely transparent that it can hardly be detected until subjected to the action of some dye, when

it shows a slightly granular character. All of these parts are so delicate, bear so little manipulation, and take dyes so poorly that it is extremely difficult to determine their exact structure. What the function of this enveloping membrane is, can only be stated conjecturally. Huxley says that Semper has found that the "anchor-like" spicula of the *synapta* are developed in sacs lined with *epithelium*. If this be true, one might reasonably conceive that this sac served some such purpose in the production of this *compound spiculum*, as this ball of wheels might properly be termed. The true connection between the ball of wheels and the integument, I have never been able to make out. As none of the dyes I have yet used seem to differentiate the parts, the study of any of these structures of the animal is very unsatisfactory. All that can be seen is that the common integument is very thin, over the ball of wheels. If this is pricked slightly and pressure applied, the ball will escape through an opening much less than its diameter, regaining its spherical shape as soon as liberated, or rather assuming it, for while buried in the integument it is more or less compressed. The places where these balls are may readily be detected, for they show through the thin integument, shining like silvery spots, slightly elevated above the surrounding skin and scattered about without regularity.

The loss of these balls of spicula appears in no way to injure the animal, for I have gently scraped the sides of many of them, liberating numbers of these balls without apparent injury. It is true one must not expect signs of pain from a creature of so low an order of development. Indeed, instead of the loss of these balls being an injury, I think they are being constantly shed by the animals, for I have found them lying loose in the vessels where the animals have been confined, and when they had not been subjected to rough handling. Neither do I see how animals, living as they do in sand, and crawling about under stones and working themselves into the narrow places where I have found them, can escape without rubbing off more or less of them. The skin over many of the balls appears very thin and ready to break at the slightest touch, over others it is much thicker. It would seem from this that they gradually worked their way through the integument, something as an abcess or foreign body does in our flesh. Then again I have found animals with the balls

very numerous on some parts of their bodies and very scarce on others. I think from these facts we may believe that shedding of these balls is a natural process, or at least that the loss of them is not a material injury. Whether these balls which are lost are replaced by new growths, I cannot say. It is not rare to find balls with only five or six wheels in the integument of adult animals; but I have not yet seen partly-formed wheels, as the evident beginning of a new sac; sometimes I have seen a single wheel by itself, but it always seemed to be abnormally so placed. In the ordinary contracted condition of the animal, the integument is thrown into numerous little elevations, with folding of the skin between: while there is no real order, it looks something like the papillation of the skin of our fingers. The balls of wheels are located in these papillæ, many of them, however, are without balls; either the ball has been lost or has not yet formed. When one is displaced it leaves so slight an injury that I have no doubt all traces are quickly removed.

That at least one shedding of these balls takes place, is evident from the fact that in the very young animals most of the wheels have more than six spokes, whereas in the adult to find one with more than six is very rare. When this change takes place, I know not, for I have never seen any animals between the very young—about the size of a very small pin-head—and the fully-developed animals, over an inch long. This, to me, is another very curious fact, that the majority of wheels in the very young should have six, seven, eight, and even thirteen spokes, when the adult is almost entirely limited to six. Otherwise I can see no difference.

It is interesting to see the progressive steps of development. The point of ossification, as the anatomist would say, is the central axis, which at first looks like a many-pointed star, the immature spokes. These increase in length till they reach the ordinary limit, when the outer end begins to expand and becomes T-shaped, the transverse portions growing out till they touch one another and complete the tire or rim.

Having examined the most striking and characteristic of the spicula afforded by the *Chirodota*, we will turn our attention to the remaining varieties, of which there are three.

The first kind we will describe is found in the common integ-

ument, occupying the top of the papillæ, generally the same as the balls of wheels do, some of the papillæ having both kinds. Generally there are only five or six of these in a papilla, and when they are present with the ball of wheels they lie around the ball, not over it. They are not at all abundant, and a careless observer might miss them entirely. They are long and slender, generally curved, some almost C-shaped, and all are more or less enlarged at the ends.

The second kind is found in the longitudinal muscles. These are larger, more distinctly enlarged at the ends than the other, and the surface seems quite rough.

The third kind is found in the tentacles which surround the mouth. These are very elegantly shaped and abundant, being arranged in two rows, one on each side of the branches of the tentacle. They form a sort of skeleton to these otherwise soft organs, yet permit extreme flexibility, serving much the same purpose the coiled wire does in the flexible gas tube. The animal extends these tentacles round its throat like a beautiful wreath and then draws them completely out of sight. To admit this extreme flexibility something besides an ordinary jointed skeleton is required, so nature has designed this system of elongated spicula, arranged in rows so as to make a flexible support.

Having given something of an examination to the spicula, it may prove interesting to learn something of the creature which bears them, and its habits. The *Chirodota* belongs to the *Synaptidæ* a subdivision of the *Holothuroidea*, or "sea cucumbers," "sea slugs" and "trepangs," as they are variously called in different parts of the world. *Holothuroidea* is a subdivision of the *Echinodermata*, which includes also the "sea stars," or "star fishes," and the "sea urchins." The *Chirodota* shows its family connection by the five longitudinal muscles which radiate from the circumoral calcareous plates. It and its near relation, the *Synapta* differ from the rest of the Holothurians, in having no ambulacral system, and in being more slender and worm-like in form. When I first saw one, I took it for a common earth-worm; but a closer examination showed no annular structure, and the ends were not so sharply pointed. When the tentacles are projected, the resemblance is slight, indeed. It has two sets of muscles; one the longitudinal

ones already mentioned, and circular ones, which pass around the animal under the whole extent of the integument. A curious feature is their great extensibility, both in length and circumference. In searching for them under stones and in the sand just at low-water mark, one may see a creature stretched out five or six inches, with neither end visible; one may be in the sand and the other under a stone, and he may think he has found a "whopper;" but touch it, and it quickly contracts to less than two inches. Or you may find one with a portion of the body swollen to two or three times its usual size, as if it had eaten something which had disagreed with it; but if you watch it a while, you may see the swelling pass, with a wave-like motion, from one extremity to the other; sometimes the whole circumference is involved, or it may be wholly a "one-sided" affair. One might easily suppose it troubled with indigestion, for its food is almost wholly, if not entirely, sand. The sand constitutes the *solid* portions of its food, for I presume it derives some sustenance from matters floating in the sea water, ample arrangements being made for its introduction to every part of its body. Then again, the young I have spoken of increased in size in clean glass vessels as long as I kept them supplied with fresh sea-water.

But to return to the elongations and contractions of the animal. These are due to the simple arrangement of its muscular system, and the only movement the animal executes quickly is that of contraction. Indeed, you may cut them in pieces with no sign of pain or writhing; the severed parts simply contract a little more. The contractile power of the circular muscles does not seem to be as fully developed in the *Chirodota* as in the *Synapta* and other members of this quiet, but over-sensitive family, for if you take the *Synapta* out of his native sandy shore and confine him in a vessel of salt water, unless you are particular to change the water frequently, he straightway begins to commit suicide by cutting himself into numerous pieces, some not more than half an inch long. He contracts these circular fibers, and cuts himself in two as neatly as one could do it with a pair of scissors. In some of the larger members of the family the contractile power is so great, they will force out all of their internal organs, and the strangest part of all is, will proceed to fit themselves up anew with another set. What a boon such powers

would be to certain dyspeptic individuals of our own race! Reject the old, and fit themselves with new and improved organs! This may seem beyond all belief, but I have witnessed part of the operation myself. If a star-fish may reproduce four-fifths of itself, why may not a Holothurian reproduce what he loses?

As has been stated, the *Synaptidæ* are destitute of the ambulacral system which other members of the family possess as organs of locomotion. The question then arises, how do these animals move? In the systematic works on Natural History, which speak of the subject at all, it is stated that motion in the *Synapta* is aided by curious "anchor"-shaped spicula, which protrude from the integument and thus serve as means to propel it. With all due deference to these writers, I must beg leave to say I do not think they serve any such purpose at all. The *Chirodota* does not possess any such spicula, and yet moves and exists under, as near as possible, the same circumstances as the *Synapta*. One would suppose, therefore, if under the same circumstances the "anchors" were of real use in the progression of the *Synapta* that the *Chirodota* would be supplied with analogous apparatus to effect the same purpose. Then again, if the "anchors" were really intended to aid in locomotion, one would naturally expect to find them arranged systematically, and with their points all inclined one way, and that way *from* the head; such, however, is not the case, for the anchors point sideways, and as many point to the left as to the right. By some it may be regarded supererogatory to inquire how an animal moves with so many wheels as the *Chirodota*, or how one can move at all with so many "anchors" as the *Synapta*, but I think it clear we shall have to look elsewhere for the locomotive power, and that I am convinced resides in the wreath of tentacles which surrounds the mouth. These may aptly be termed the *hands* of the animal. These organs may be described as hands with narrow palms, with five or six fingers on each side. The palmar surface faces outwardly, and by their help I have seen both the *Synapta* and the *Chirodota* crawl or lift themselves a little way up the side of a glass vessel. It is hardly supposable that the points of the "anchors" penetrate the smooth surface of the glass. Moreover, I have seen the very young chirodota cling to the bottom of the vessel by spreading out all its ten-

tacles with its little sac-like body standing straight up; virtually standing on its head, and in this way would slowly move about.

Concerning the use or need of these "wheel"-like spicula, I am entirely in the dark. They have no analogue, so far as I can find, in the whole Holothurian family. That they are not analogous to the spicula found throughout the family as a rudimentary skeleton which finds its highest development in the *Echinoidea* or "sea urchins," I think is clear. I believe this to be established by the very different mode of growth and development, and the very good reasons we have for believing that they are shed or thrown off by the animal without apparent injury, and by the additional fact that there is a variety of spicula, (the C-shaped) which fully answers all the requirements for carrying out the structural plan of the group. To me they are as inexplicable as are the *pedicelli* of the "sea urchins." or the "bird's heads" of the *Polyzoa*.

One can hardly believe that objects of such beauty and exquisite perfection, and the elaborate methods involved in their construction can be all for naught; but for a satisfactory explanation of their use in the economy of the animal we must await the result of further investigation. Whatever may be the developments of further research, one cannot rise from the study of such strangely beautiful objects, formed in such a curious way, in such a humble creature, without a feeling of more profound veneration for that Power which stamps upon the lowliest of his creatures the evidences of loving care.

EXPLANATION OF PLATE II.

ILLUSTRATING SPICULA OF CHIRODOTA OF BERMUDA.

Fig. 1. Wheel-like spiculum viewed as an opaque object.

Fig. 2. Sectional view of a "wheel," showing the slope of the "tire," or rim, the "cogs," or notching of the upper edge, the curve of the spokes, and the conical projection from the center of the "hub" downward; a, sectional view of one of the spokes.

Fig. 3. A "wheel" mounted in balsam, showing the "tire" as flat, and beveled between the spokes, and their tenon like insertion in the "hub,"—optical effects produced by transparency of the material of which the spiculum is composed.

Fig. 4. A ball, or sphere of "wheels" attached by the "umbilical cords" to a central mass. Their regularity of position has been disturbed by mounting.

Fig. 5. Sectional view of a ball of "wheels," showing the "umbilical cords" with their lobed expansions to the spokes, and which also embrace the conical point in the center of the "hub;" also their origin from fibers of the central mass. This figure also shows the "periosteum" or nutritive membrane, the solid portions of the "wheel" having been dissolved out.

Fig. 6. Spicula, C shaped, from the common integument, generally found in the papillæ, near the ball of "wheels."

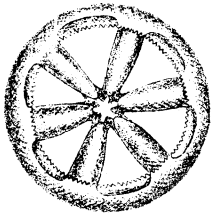
Fig. 7. Spicula from the longitudinal muscles.

Fig. 8. Spicula from the tentacles.

Fig. 9. Different stages of development of the wheel-like spicula. The T like expansions of the spokes finally coalescing to form the "tire." From the very young animal.

PLATE II.

Fig. 1.



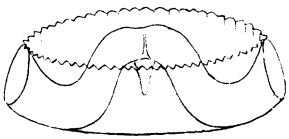


Fig. 2.

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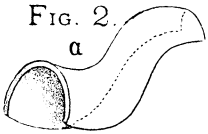

Fig. 3.

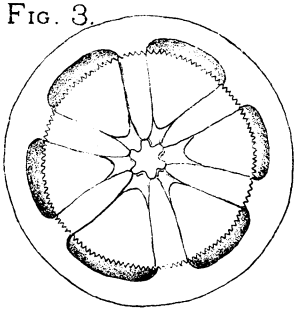

Fig. 4.

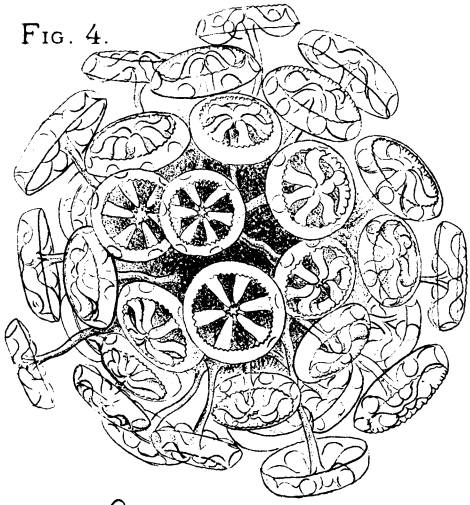

Fig. 5.

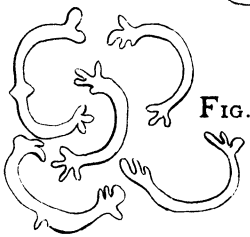

Fig. 6.

Fig. 7.

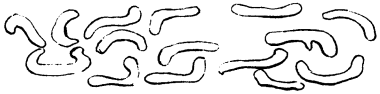

Fig. 9.

Fig. 8.